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Isotopic study (^{18}O, ^{2}H) of the ground water in the Bekaa's plain (Lebanon)

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Abstract

The stable isotopes of the water molecule (^{18}O, ^{2}H) give informations about the paleoclimate existing during the water seepage and about the recharge conditions of the groundwater. The effects of the Orography, the Continentality, and the origin of the masses of air have an effect on the isotopic abundance of the precipitations (rain + snow) in Lebanon. An evaporation of the recharge water exists in the atmosphere, with a mixing between the deep water and the shallow ones. The sea water has an isotopic abundance at 0 ‰ (SMOW : Standard Mean Ocean Water) for $\delta^{2}H$ et $\delta^{18}O$, the Mediterranean Sea is at the origin of the rains which fall on the studied area, and which do not keep the isotopic abundances of the sea because the high mountains that they cross during their movement. This high altitude causes an impoverishment of the water of the rain on heavy isotope (^{18}O).

Key words: isotopes, oxygen 18, deuterium (^{2}H), Bekaa, Lebanon.

1. INTRODUCTION

The valley of Bekaa is the study area existing between 35° 37' and 36° 37'°E, 33° 32' and 34° 21'°N, which has an average altitude about 900-1000 m (above sea level) and which separates the east lebanese mountains' chains (Anti-Lebanon) from the west ones (Mount-Lebanon), but the study concerns the west side of the Anti-Lebanon and the east side of the Mount-Lebanon. The two mountainous chains represent the recharging areas (rain water, snow mainly) of the groundwater in the valley e.g. [1]. The samples were taken during 4 missions of sampling carried out

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between (marsh 2003–december 2004) in Lebanon where 19 wells and 22 sources were studied (Transects A, B, C and D) (Figures 1 and 2).

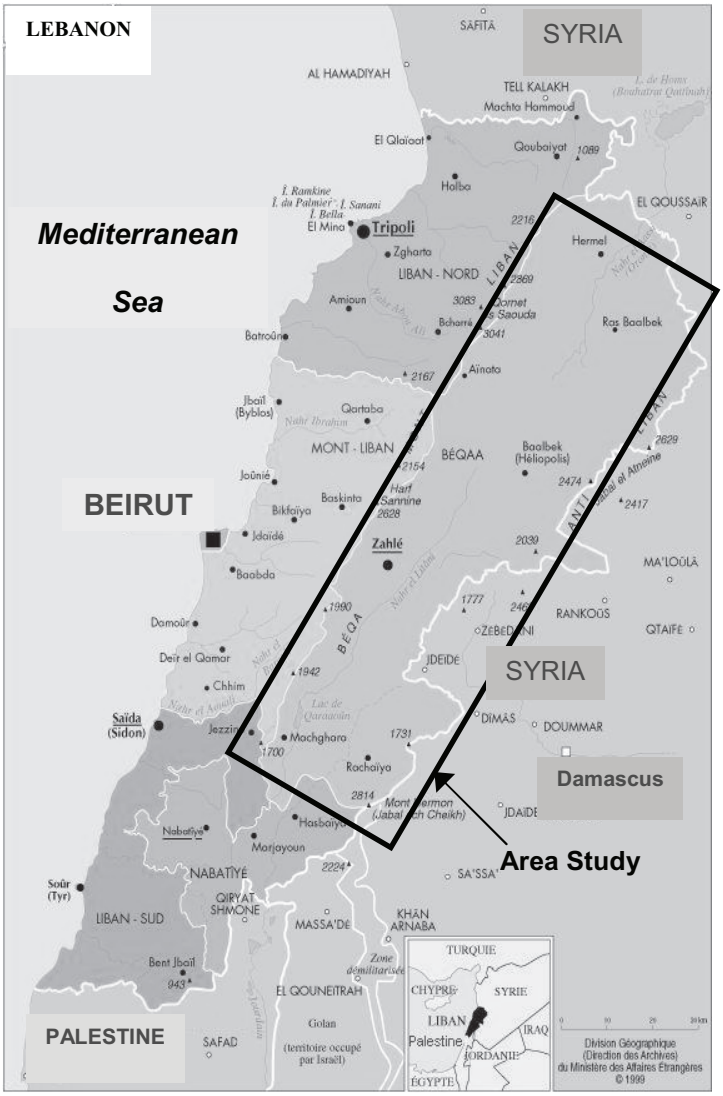

Figure 1: the localisation of the valley of Bekaa in Lebanon.

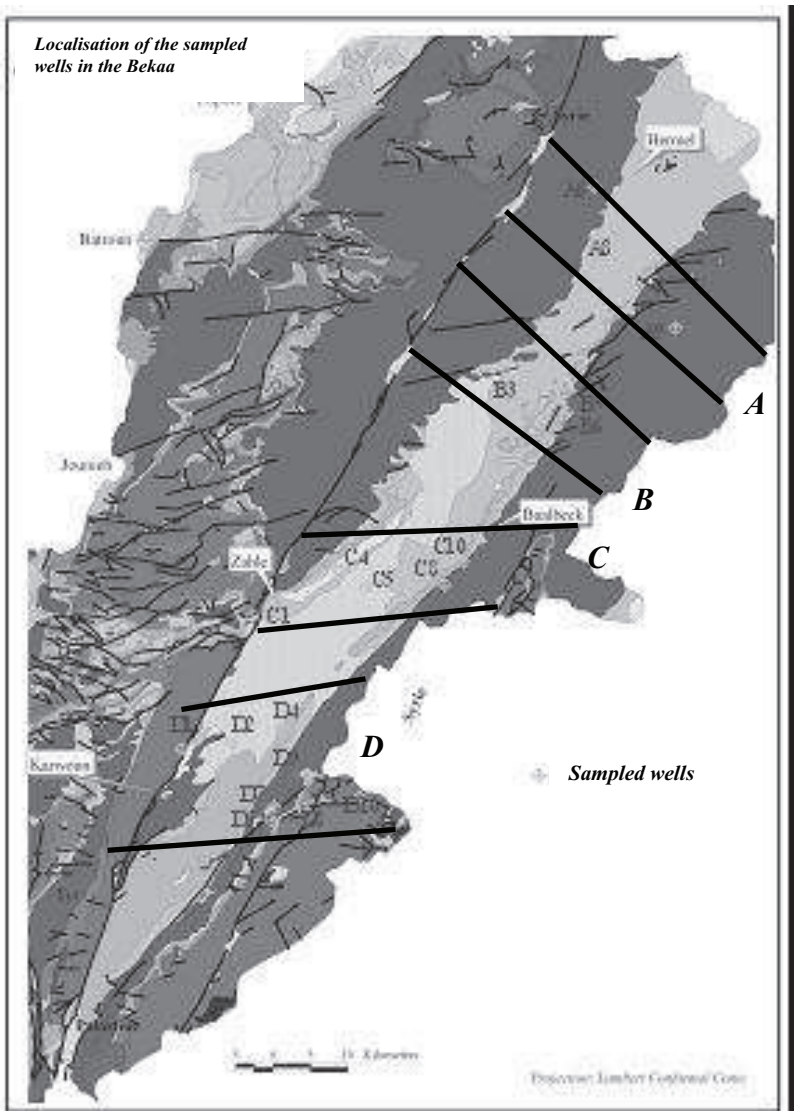

Figure 2 : the transects of study in the valley of Bekaa.

2. ISOTOPIC ASPECT

The isotopic values in $\delta^{18}O$ ‰ for the 41 samples of water are between -9.91 (cf. Hermel : El Adim source (S9)) and -6.13 (cf. wells D6 : Mdoukha and D7 : Al Dakoui) for an average about -7.83 ± 0.86 vs SMOW, and between -62.01 ‰ (cf. Hermel : Râs El mal source (S8)) and -35.78 ‰ (cf. well of Al Dakoui (D7)) for an average about -47.41 ± 3.69 ‰ vs. SMOW for the $\delta^{2}H$. For the sampled wells, the isotopic values in $\delta^{18}O$ ‰ are between -9.33 (cf. well of Wadi El Karm (A6)) and -6.13 (cf. wells D6 : Mdoukha and D7 : Al Dakoui) with an average about -7.55 vs SMOW, and between -61.31 ‰ (cf. well of Wadi El Karm (A6)) and -35.78 ‰ (cf. well of Al Dakoui (D7)) for an

average about -45.12 ‰ vs. SMOW for the δ^2H. The isotopic values in $\delta^{18}O$ ‰ of the water of the sources are between -9.91 (cf. Hermel : El Adim source (S9)) and -6.61 (cf. Mdoukha : El Chwaiti source (S23)) for an average about -8.13 vs. SMOW, and between -62.01 ‰ (cf. Hermel : Râs El mal source(S8)) and -38.99 ‰ (cf. Mdoukha : El Chwaiti source (S23)) for an average about -49.71 ‰ vs. SMOW for the δ^2H (Table 1 and Figure 3). The equation of the line which relies the values of δ^2H and $\delta^{18}O$ for all water analysed (wells and sources) is : $\delta^2H = 6.9 * \delta^{18}O + 6.3$ ($n = 41$, $r^2 = 0.81$). All the points are between the World Meteoric Line ((WML : $\delta^2H = 8 * \delta^{18}O + 10$ (Craig, 1961)) and the East Mediterranean Meteoric Line (EMML: $\delta^2H = 8 * \delta^{18}O + 22$) (Gat & Carmi, 1970). A slope about 6.9 indicates a low evaporation of recharging's water. The line $\delta^2H = 6.9 * \delta^{18}O + 6.3$ goes across the axis of δ^2H and joins the EMML at a value about -90 ‰ vs. SMOW corresponding to $\delta^{18}O$ = -14 ‰ vs. SMOW, we conclude that these groundwaters have as origin a recharging's water with an isotopic values about -14 and -90 ‰ vs. SMOW respectively in Oxygen-18 and in Deuterium. These values relatively impoverished can correspond to the isotopic values of water which comes from the snows' thawing covering the mountainous massifs and which have an essential role in the aquifers' recharging (piezometric domes at the high snowy altitudes represent the recharging's areas).

Table 1: the values in stable isotopes (^{18}O, ^{2}H) of the groundwater of the study area.

Site	Date	Reference	Nature	δ^2H ‰ (vs. SMOW)	$\delta^{18}O$ ‰ (vs. SMOW)	d (excess in Deuterium)
Mount-Lebanon						
Jdita	05/04/2003	C1	Well	-43.99	-7.74	17.93
Jdita	05/04/2003	S1	River	-47.64	-8.07	16.92
Kefrayia	17/04/2004	D1	Well	-36.84	-6.15	12.36
Kefrayia	17/04/2004	Wadi el jaouz (S18)	Source	-40.93	-7.16	16.37
Nabi eila	07/04/2003	C4	Well	-44.62	-7.64	16.50
Nabi eila	07/04/2003	S2	Source	-42.98	-7.05	13.42
Niha	07/04/2003	S3	Niha Source	-46.10	-7.72	15.66
Wadi el karm	10/04/2003	A6	Well	-61.31	-9.33	13.33
Yammouneh	22/04/2003	S4	El Arbiin Source	-55.91	-9.61	20.97
Yammouneh	22/04/2003	S5	El Moghr Source	-51.23	-8.52	16.93
Bekaa						
Ammick	17/04/2004	D2	Well	-39	-7.64	22.11
Ammick	17/04/2004	S19	Pond	-39.43	-6.49	12.46
El Mansoura	17/04/2004	D4	Well	-40.92	-7.12	16.06
Hermel	09/04/2003	S6	Aîn el zarqa Source	-50.85	-8.62	18.11
Hermel	10/04/2003	S7	Bdaîta Source	-58.88	-9.60	17.92
Hermel	10/04/2003	S8	Ras el mal Source	-62.01	-9.07	10.55
Hermel	10/04/2003	S9	El adim Source	-60.91	-9.91	18.37
Laboueh	09/04/2003	S10	El Laboueh Source	-55.11	-7.84	7.61
Maqneh	12/04/2003	B3	Well	-51.50	-8.22	14.26
Qasr- Hermel	27/04/2003	S11	Ebbish Source	-51.59	-8.04	12.73
Rayack	05/04/2003	C5	Well	-46.58	-8.08	18.06
Tal el akhdar	24/03/2004	S20	Pond	-35.34	-6.16	13.98
Zabboud	09/04/2003	A8	Well	-45.67	-7.26	12.41
Anti-Lebanon						
Aîn Arab	18/04/2004	Aîn Baqa (S21)	Source	-40.53	-6.87	14.42
Aîn Arab	24/03/2004	S22	Pond	-23.92	-4.49	12.02
Aîta el Foukhar	19/04/2004	D9	Well	-39.17	-6.59	13.58
Aîta el Foukhar	19/04/2004	Al Arich (S26)	Source	-42.08	-7.75	19.95
Al Dakoui	17/04/2004	D7	Well	-35.78	-6.13	13.28
Bakka	18/04/2004	D8	Well	-38.72	-7.02	17.43
Bakka	18/04/2004	Aîn el Baîda (S24)	Source	-39.59	-7.52	20.57
Bakka	24/03/2004	S25	Pond	-29.1	-5.16	12.21
El khedr	05/04/2003	C10	Well	-47.28	-7.21	10.40
Fakihé	16/04/2003	S12	Source	-55.96	-8.51	12.12
Haloua	19/04/2004	D10	Well	-42.99	-7.68	18.43
Ham	08/04/2003	S13	El Khandaa Source	-46.86	-7.50	13.14
Ham	08/04/2003	S14	Aîn el sghiré Source	-47.05	-7.49	12.87
Mdoukha	19/04/2004	D6	Well	-39.33	-6.13	9.67
Mdoukha	19/04/2004	El Chwaiti (S23)	Source	-38.99	-6.61	13.90
Nabi Chit	05/04/2003	C8	Well	-45.87	-8.18	19.57
Orsal	09/04/2003	A9	Well	-55.25	-8.86	15.63

Orsal	09/04/2003	S15	Aîn el choob Source	-52.94	-7.81	9.54
Orsal	09/04/2003	S16	Riyan Source	-58.25	-9.31	16.23
Younin	12/04/2003	B6	Well	-52.03	-8.47	15.73
Younin	14/04/2003	B5	Well	-50.46	-7.91	12.82
Yahfoufa	08/04/2003	S17	Source	-47.19	-8.22	18.57
Average Wells	-	-	-	-45.12	-7.55	15.24
Average Sources	-	-	-	-49.71	-8.13	15.31
General average	-	-	-	-47.41	-7.83	15.27

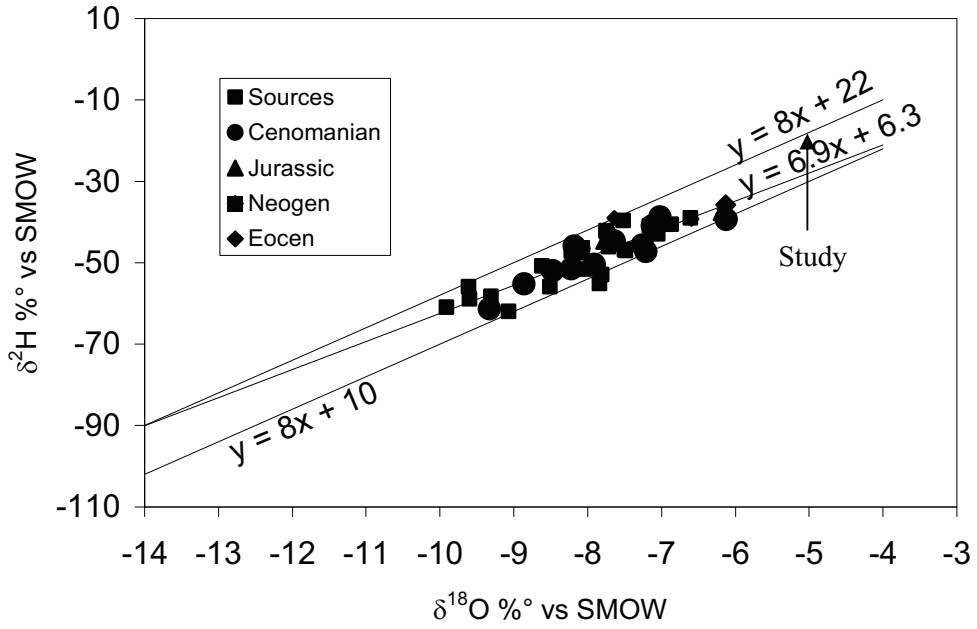

Figure 3 : the Deuterium vs. Oxygen-18 (the band of errors = ± 2 ‰ & ± 0.2 ‰ vs. SMOW respectively).

3. GROUNDWATER'S ISOTOPES

The water of Cenomanian indicates the weakest isotopic values in oxygen-18 (cf. El Adim source in Hermel (S9) ; $\delta^{18}O$ = -9.91 ‰ vs. SMOW) and in Deuterium (cf. Râs El mal source in Hermel (S8) ; $\delta^{2}H$ = -62.01 ‰ vs SMOW) (Table 2), with a very great variation in isotopic values in $\delta^{18}O$ which are between -9.91 (cf. El Adim source in Hermel (S9)) and -7.02 (cf. well of Bakka (D8)) for an average about -7.7 ‰ vs SMOW, and in $\delta^{2}H$ with values which are between -62.01 and -38.72 with an average about -47.8 ‰ vs. SMOW. The water of Jurassic have isotopic values which are between -8.07 and -6.15 for an average value about -7.2 ‰ vs. SMOW for the Oxygen-18 and between -47.64 and -36.84 for the Deuterium for an average about -41.3 ‰ vs. SMOW. The waters of Eocen (cf. well Al Dakoui : D7) present an isotopic values about -6.13 ‰ for the $\delta^{18}O$ and -35.78 ‰ for the $\delta^{2}H$ (vs. SMOW).

These differences in isotopic values between the aquifers are due to the difference in the altitude of the recharging of these formations (Figure 4). The aquifer of Cenomanian which is the more impoverish in $\delta^{18}O$ comes up to the highest summit of the lebanese mountains (Mount-Lebanon and Anti-Lebanon) but the Jurassic comes up to the shallow altitudes e.g. [2] and [3]. The Eocen and Neogen go up to the surface at shallow altitudes near of the border of the valley of Bekaa. The isotopic values of the sampled water in the Bekaa are sensitive to the evaporation.

Table 2 : the isotopic values (^{18}O, ^{2}H) of the water of the different aquifers.

Site	Nature	Jurassic		Cenomanian		Eocen		Neogen	
		^{2}H	^{18}O	^{2}H	^{18}O	^{2}H	^{18}O	^{2}H	^{18}O
Mount-Lebanon									
Jdita	Well	-43.99	-7.74	-		-		-	
Jdita	River	-47.64	-8.07	-		-		-	
Kefrayia	Well	-36.84	-6.15	-		-		-	
Kefrayia	Source	-40.93	-7.16	-		-		-	
Nabi eila	Well	-		-44.62	-7.64	-		-	
Nabi eila	Source	-		-42.98	-7.05	-		-	
Niha	Niha source	-		-46.10	-7.72	-		-	
Wadi el karm	Well	-		-61.31	-9.33	-		-	
Yammouneh	El Arbiin source	-		-55.91	-9.61	-		-	
Yammouneh	El Moghr source	-		-51.23	-8.52	-		-	
Bekaa		-				-		-	
El Mansoura	Well	-		-40.92	-7.12	-		-	
Hermel	Aîn el zarqa source	-		-50.85	-8.62	-		-	
Hermel	Bdaîta source	-		-58.88	-9.60	-		-	
Hermel	Ras el mal source	-		-62.01	-9.07	-		-	
Hermel	El adim source	-		-60.91	-9.91	-		-	
Laboué	El Laboueh source	-		-55.11	-7.84	-		-	
Maqné	Well	-		-51.50	-8.22	-		-	
Qasr- Hermel	Ebbish source	-			-		-	-51.59	-8.04
Rayack	Well	-			-		-	-46.58	-8.08
Zabboud	Well	-		-45.67	-7.26	-		-	
Anti-Lebanon		-			-		-	-	
Al Dakoui	Well	-			-	-35.78	-6.13	-	
Bakka	Well	-		-38.72	-7.02	-		-	
El khedr	Well	-		-47.28	-7.21	-		-	
Fakihé	Source	-		-55.96	-8.51	-		-	
Haloua	Well	-42.99	-7.68		-		-	-	
Ham	El Khandaa source	-46.86	-7.50		-		-	-	
Ham	Aîn el sghiré source	-47.05	-7.49		-		-	-	
Mdoukha	Well	-		-39.33	-6.13	-		-	
Nabi Chit	Well	-		-45.87	-8.18	-		-	
Orsal	Well	-		-55.25	-8.86	-		-	
Orsal	Aîn el choob source	-		-52.94	-7.81	-		-	
Orsal	Riyan source	-		-58.25	-9.31	-		-	

Younin	Well		-		-52.03	-8.47		-	-
Younin	Well		-		-50.46	-7.91		-	-
Yahfoufa	Source		-		-47.19	-8.22		-	-
General average		- 41.30	-7.20	- 47.80	-7.70	-35.78	-6.13	- 49.08	-8.06

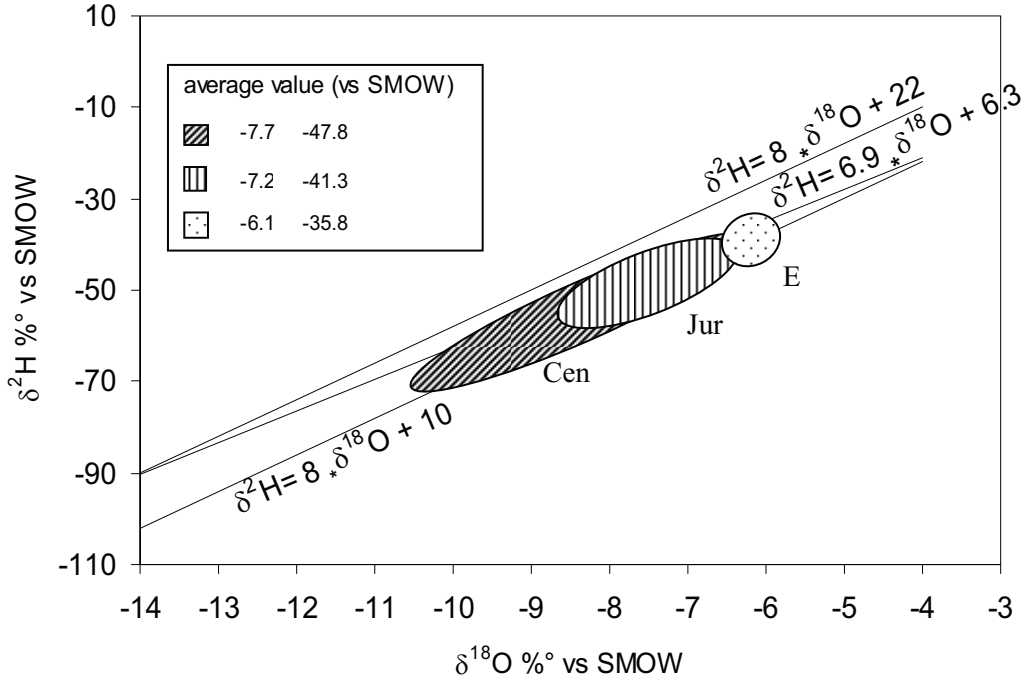

Figure 4 : the isotopic value in ^{2}H and in ^{18}O ‰ vs SMOW of the aquifers of : the valley of Bekaa, East side of Mount-Lebanon and West side of the Anti-Lebanon (Cen : Cenomanian, Jur : Jurassic, E : Eocen).

4. CONCLUSION

The orography (altitude of recharging) and the active air current on the climate in Lebanon are the origin of this great variation in the isotopic values in $\delta^{18}O$ and $\delta^{2}H$ ‰ vs. SMOW of the groundwater e.g. [4]. The recharging's water which undergoes an evaporation in the atmosphere, goes quickly to the profound layer through the cracks of the karstic system which dominates the East and the West side of Mount-Lebanon and of Anti-Lebanon respectively. The water of the Cenomanian are more impoverish in heavy isotopes than more of the water of the Jurassic, the water of the superficial aquifers (Eocen and Neogen) indicates the more enriched values ; a mixing between the water of the aquifers exists near from the principal fault area with a local pollution (fertilizer) of the groundwater in the valley of Bekaa.

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